# Space Weather Technical Forecast

Issued on Saturday, 11 November 2023 at 01:10 Local

**This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales**

## Space Weather Forecast Headline: G1 to G2 Minor to Moderate geomagnetic storm Expected over UTC weekend, Chance G3 Strong geomagnetic storm at peak. Active electron fluence Expected at GEO until this arrival.

### Analysis of Space Weather Activity over past 24 hours

**Solar Activity:** Solar activity has been Low over the UTC day of Friday 10 November, with X-rays recorded at GOES16 registering at low C-class. The largest of these flares was a C3.4 observed from AR3477 in the southwestern quadrant at 10/1604UTC. Also of note was a long-period C2.8 around 10/1930UTC from a potentially complex sub-photosphere region encompassing AR3480, 84 and 85 to its immediate east. This flare was accompanied by a modest coronal dimming, and appears to have generated a Coronal Mass Ejection (CME). This source region is in the same vicinity as that which produced the Earth-directed full halo CME of 09 November, which currently dominates the geomagnetic forecast, although this event appears much more modest and has yet to be confirmed.

There are now six numbered sunspot regions on the solar disc, with these all somewhat clustered in the western solar hemisphere and especially in the southwest. The most complex group on the current facing side remains AR3483 in the northwestern quadrant, which is currently designated as a Dai/Beta-Gamma. This area showed proliferation and spreading of its intermediate spots in the period, with these subsequently migrating to form a complex leader and perhaps a tenuous delta spot candidate in its trailing spots. Other developments of note were AR3484 showing proliferation throughout, but remaining a relatively simple region, while AR3485 developed to a small bipolar region from plage.

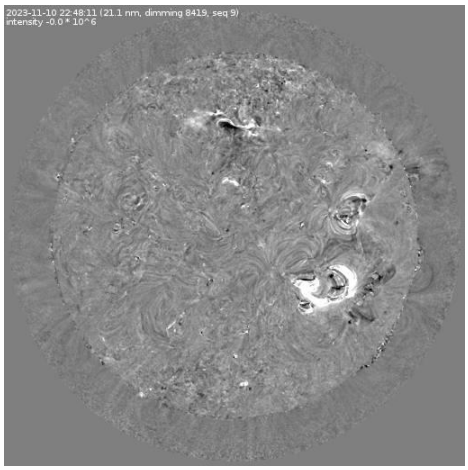


**Figure 0: SIDC ROB-processed time-integrated AIA211 dimmings of note in the past 24 hours, i.e. a southwest-centred event tied to the C2.8 flare between AR3480, 84 and 85 peaking 10/1930UTC, and also the possible filament eruption from the north-centre disc around 10/2130UTC. Only the former has any confirmed ejecta at present, and both have yet to be analysed for any CME.**

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Coronagraphs for the 24 hours showed a far-sided eastern solar hemisphere CME of uncertain origin, a non-Earth directed southwest limb event around 10/1200UTC as well as some high latitude activity in the northwest (i.e. off-ecliptic). At the time of writing, a late-UTC day apparently westward-heading CME was becoming visible in Lasco C2, probably associated with the long-period C2.8 at 10/1930UTC from the vicinity of AR3480, 84 and 85. Modelling of this event will be conducted in due course. A final candidate for a CME was observed at high latitudes near the solar meridian in extreme UV (AIA211) at 10/2130UTC, perhaps a filament lift-off, although no H-alpha imagery captured the event. Any CME is awaited in imagery. No new Earth-directed CMEs were therefore in evidence.

**Solar Wind / Geomagnetic Activity:** Solar winds, as observed at L1 by ACE and DSCOVR, showed very different tendencies, but overall are felt to be reflective of the waning enhancement from a high speed stream associated with CH67/-.

With ACE measurements taken in preference, solar wind speeds fell from Strong to Elevated: in the 600s of km/s to high-500s. The solar wind density was steady in single figures ppcc, while the total interplanetary magnetic field strength (Bt) was steady at or below 3nT, with a varying Bz component within +/-3nT. The phi angle remained predominantly negative (towards the Sun), with just a few brief variations.

The net result of the above solar wind measures was for provisionally Quiet to Unsettled geomagnetic indices, peaking at Kp '3o' in the 03-06UTC interval.

**Energetic Particles / Solar Radiation:** GOES16 high energy (greater than 10MeV) proton flux fell from a peak value of 2.7pfu at 10/0015UTC, to approach resting background levels around a decade lower by the UTC evening. The peak level was attained in response to the C2 flare and associated 09 November Earth-directed CME.

GOES16 high energy (greater than 2MeV) electron flux showed a diurnal oscillation mostly within High levels, peaking at 3910pfu at 10/1850 UTC. The associated 24-hour fluence gradually increased through the period, with the fluence observation at 11/0001UTC being 1.56e8 integrated pfu.

## Four-Day Space Weather Forecast Summary

**Solar Activity:** Solar activity carries a daily Slight Chance of increasing to Moderate, although recent flare activity has been Low and is therefore perhaps the least noteworthy aspect of the forecast.

**Solar Wind / Geomagnetic Activity:** One CME from the southwest quadrant 10/1930UTC is awaiting imagery for assessment, with a second candidate for a CME also seen at 10/2130UTC. The geomagnetic forecast is otherwise dominated by the expected arrival of the 09 November full halo CME, currently posited for 12/0001UTC. G1 to G2 Minor to Moderate geomagnetic storms are Expected at peak, with a Chance of G3 straddling the midnight separating both UTC days. Geomagnetic activity leading up to and subsequent to this is expected to be much quieter, most reliably so to end the four-day period.

**Energetic Particles / Solar Radiation:** There is a daily Slight Chance of S1 or greater should any of the western solar hemisphere sunspot groups produce suitable flares in the period. This risk should begin to wane towards the middle of the coming UTC working week.

High energy electron flux (greater than 2MeV) is expected to continue near current levels at first but shoudl be significantly attenuated at GEO upon the arrival of the 09 November CME, with a roughly evens chance of Active fluence surviving into the start of the UTC day of Sunday 12



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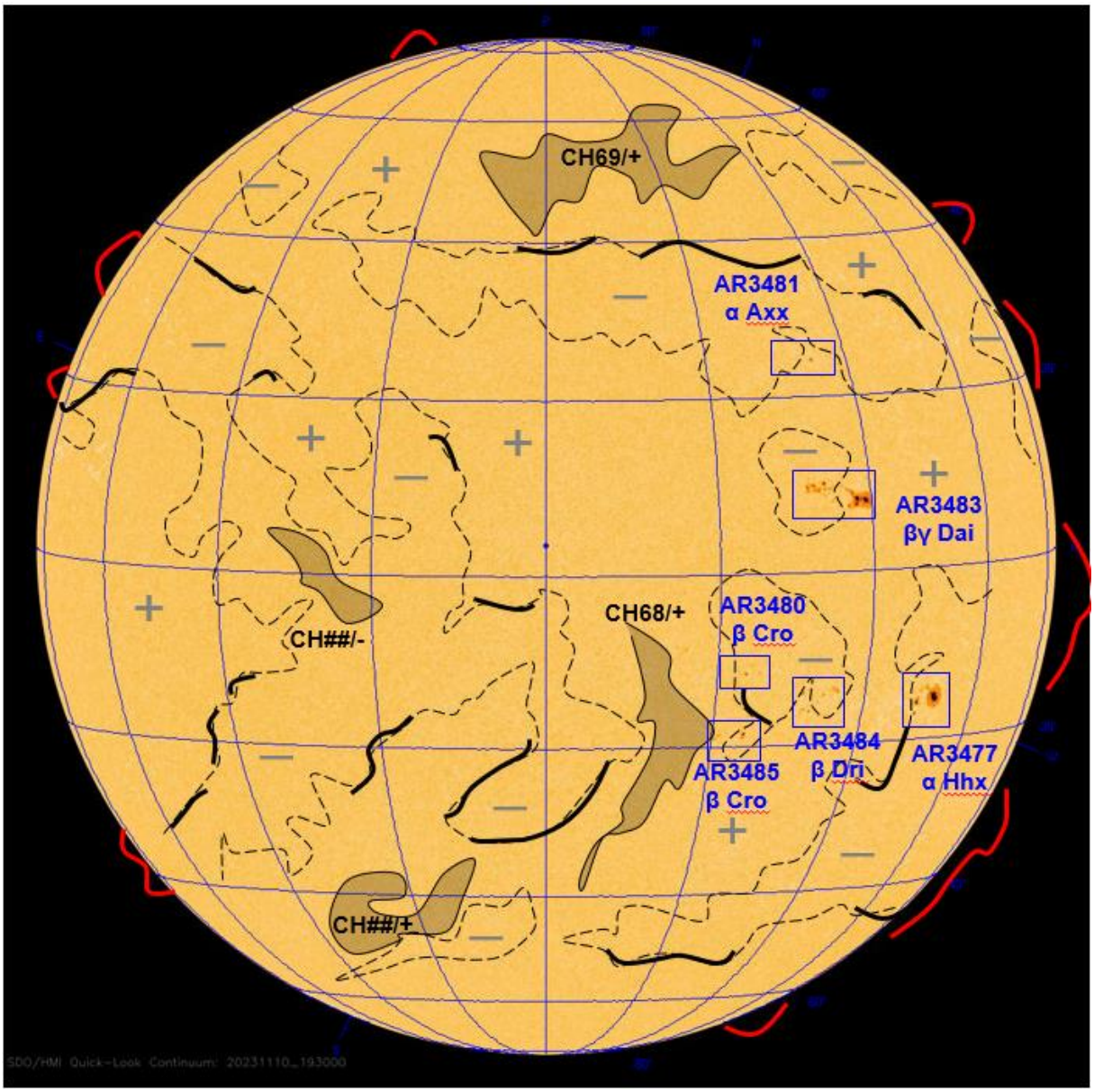
November. Once suppressed, there is a Chance of recovery at GEO as the new UTC week develops.

**Figure 1. Solar Analysis Valid 10/1930UTC.**




**Key:** Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

## Geomagnetic Storms:

By far the most noteworthy aspect of the coming four-day period is the impending arrival of the 09 November C2 flare and major coronal dimming-associated full halo CME from near centre-disc. This feature inherently carries some uncertainty due to the very narrow perspective offered by STEREO and Lasco viewpoints, however arrival is mooted for the UTC overnight period Saturday 11 into Sunday 12 November. After numerous re-analyses, a most likely arrival has been set at 12/0001UTC. A G3 watch has been issued for this event starting 1200UTC on

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Saturday 11 November - lasting for 24 hours.

Separately from the above CME, the persistence forecast comprises largely Quiet geomagnetic conditions. Earth is expected to gradually exit the waning influence of CH67/-, prior to the CME's arrival, with Quiet to Unsettled activity predominant given the very modest IMF and despite the Elevated solar wind speed. Beyond this, current coronal holes are relatively ill-defined and given the high likelihood of transient effects, any fast wind(s) effects will be swamped and play a bit-part in the forecast.

All considered, initial Quiet to Unsettled conditions are Expected to give way to Minor to Moderate geomagnetic storms, with the peak likelihood around the turn of the UTC weekend days. There is a Chance of G3 Strong geomagnetic storms, and a Watch has accordingly been issued. Activity should wane from here, with a tail of G1 risk perhaps extending into the new working week, but an otherwise predominantly Quiet Monday and Tuesday are most likely.

| Geo-Magnetic Storm Probability (Exceedance) | Level | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) (%) | Day 2 (00-24 UTC) (%) | Day 3 (00-24 UTC) (%) | Day 4 (00-24 UTC) (%) |
|---|---|---|---|---|---|---|
| **Minor or Moderate** | **G1 to G2** | No | 70 | 90 | 20 | 1 |
| **Strong** | **G3** | No | 30 | 30 | 1 | 1 |
| **Severe** | **G4** | No | 5 | 5 | 1 | 1 |
| **Extreme** | **G5** | No | 1 | 1 | 1 | 1 |

## Geomagnetic Activity - Earthbound Coronal Mass Ejections

| Date/time 21.5R (UTC) | Halo: Full or Partial | Source | Source Location | Estimated Speed | Estimated Arrival Time | Comments |
|---|---|---|---|---|---|---|
| 19/1800UTC | Full | Vicinity of AR3480, 84 and 85. Possible filament. | Central SW | 700km/s | 12/0001UTC | Earth-directed but cone and therefore speed low confidence. |

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**Figure 2: Latest 10/1800UTC MOSWOC Enlil model run and associated ensemble, showing the 09 November CME arrival as most likely around the turn of the UTC day 11 into 12 November.**

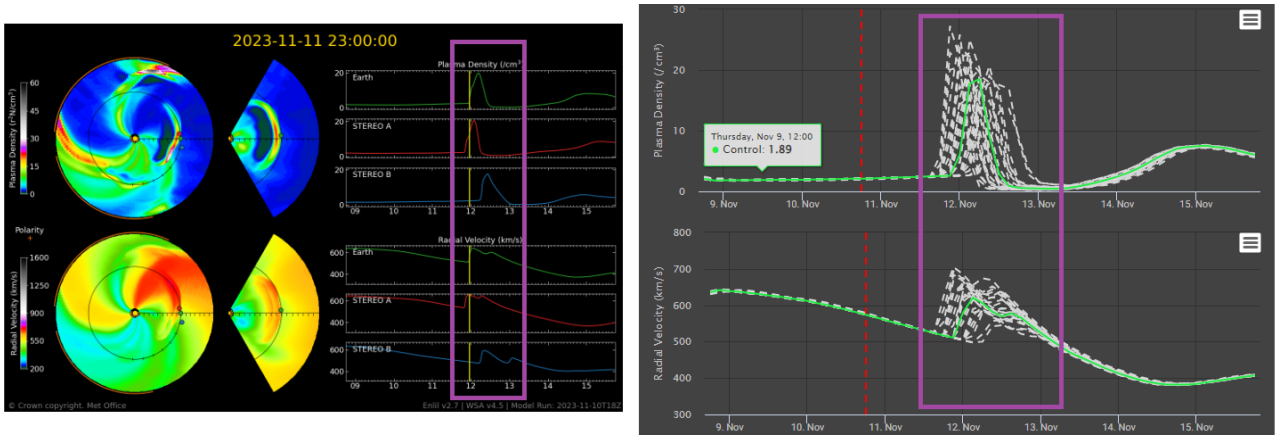
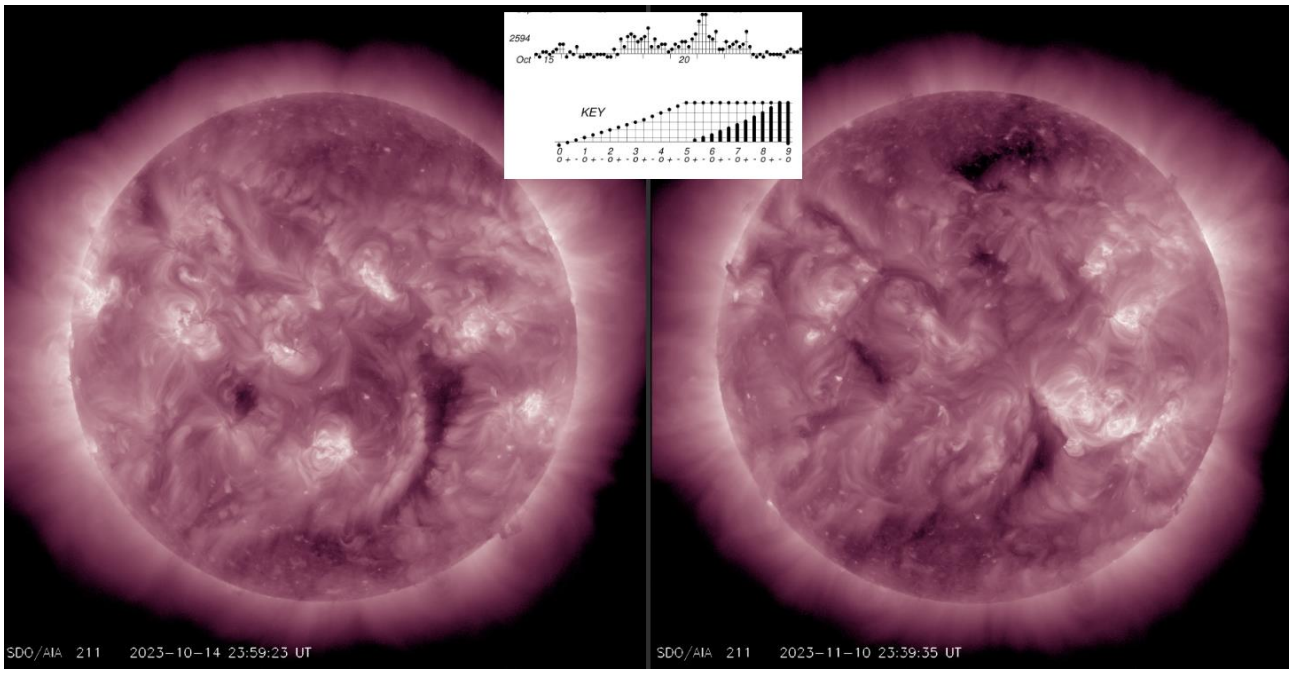



**Figure 3: AIA211 imagery from the current and previous rotations, showing dissimilarity in coronal hole configurations, but in any case relatively minor geomagnetic activity.**

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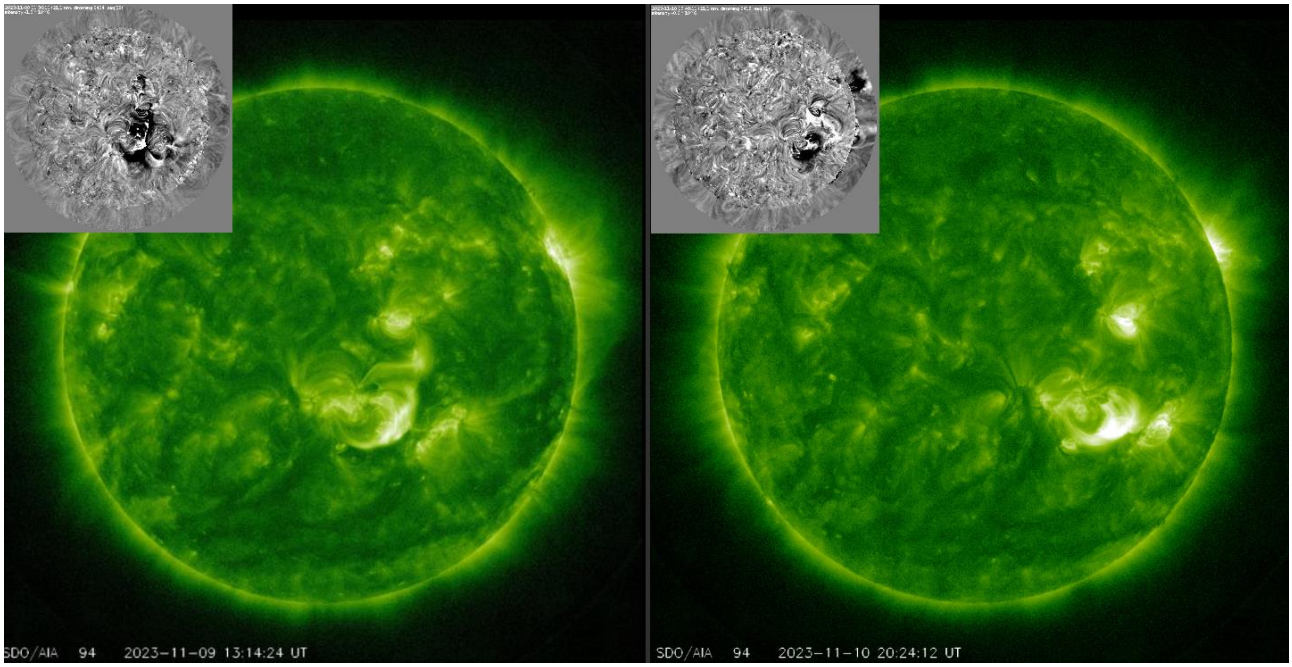
## Radio Blackouts - X-Ray Flares:

There are six numbered sunspot regions on the solar disc at present. While AR3483 is nominally the most complex group on the solar disc at present and is one to watch given its recent growth and Dai/Beta-Gamma classification, perhaps the most noteworthy portion of the disc is the plage roughly delineated by AR3480, 84 and 85 to its southeast. While the photosphere and the visible sunspot groups here are largely unremarkable at present, they appear to be magnetically connected and there are signs of a diffuse collection of pores quite widely in this region. These may go some way to hinting at sources for recent CME activity here, even if accompanying flares have so far been much more modest.

In terms of the overall balance of front-side region populations, AR3477 should depart later on Tuesday 14 November to offer a slight downturn in M-class flare risk, with soundings, persistence and flux looping all suggesting limited contributions from any returning regions over the eastern limb.

| X Ray Flares<br>Probability | Level | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC)<br>(%) | Day 2 (00-24 UTC)<br>(%) | Day 3 (00-24 UTC)<br>(%) | Day 4 (00-24 UTC)<br>(%) |
|---|---|---|---|---|---|---|
| Active | R1-R2 M Class | No | 20 | 20 | 20 | 15 |
| Very Active | R3 to R5 X Class | No | 1 | 1 | 1 | 1 |

**Figure 4: AIA094 imagery of the 09 November CME-associated C2 flare and the more recent C2.8 from 10/1930UTC. Also shown are nested AIA211 time-integrated dimmings, processing courtesy of SIDC ROB. The 10 November event has yet to be analysed, and while of lower magnitude and a more westward heading, Earth impacts cannot yet be ruled out.**

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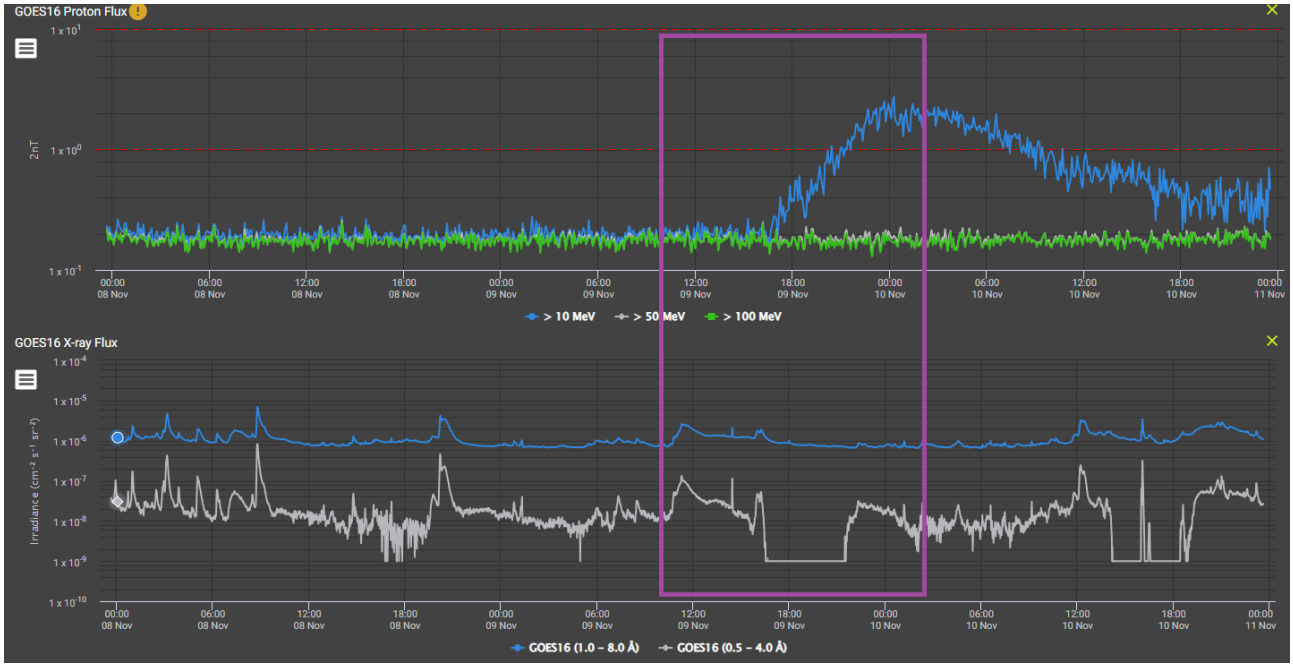
## Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is now relaxing back to a resting background level, in the wake of the 09 November long-period C2 and associated CME. While comfortably short of S1, the proton event was of respectable scale for such a small flare, and there is considered a Slight Chance of similar or greater given intervening rotation towards a better connecting part of the Sun should similar occur over the UTC weekend. The chances then begin to wane towards the middle of the coming UTC working week (i.e. just outside the current scope of the forecast) as the southwestern cluster of front-side sunspots begin to cross onto the far side.

| Radiation Storms Probability (Exceedance) | Level ($cm^{-2}$ $sr^{-1}$ $s^{-1}$) | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) (%) | Day 2 (00-24 UTC) (%) | Day 3 (00-24 UTC) (%) | Day 4 (00-24 UTC) (%) |
|---|---|---|---|---|---|---|
| **Active** | **≥ S1** | No | 10 | 10 | 10 | 10 |
| **Very Active** | **≥ S3 *** | No | 1 | 1 | 1 | 1 |

* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)

**Figure 5: Past 72 hours in GOES16 high energy proton flux and associated X-ray flux, showing possibly linked long-period C2 and slight 10MeV enhancement.**

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## High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) has shown day-on-day increases in response to the recent fast wind from CH67/-, but is expected to now be near its peak in a steady state between Moderate and High flux.

Active electron fluence is Expected on Saturday 11 November, with levels in the Van Allen belts then very likely to be attenuated upon the arrival of the 09 November CME, with fluence perhaps just surviving into Sunday 12 November before falling off sharply for a time. Geomagnetic activity should then hold levels at GEO for at least 24 hours before an uncertain degree of recovery into the new working week.

The new UTC week is unlikely to offer further significant charging of the belts, and should the CME prove dispersive in terms of GEO electron populations, any subsequent recovery is unlikely.

MOSWOC REFM is not felt to be a useful guide in this instance given the overwhelming reliance of the forecast on transient activity.

| **GEO Electron Environment** | **Level ($cm^{-2}$ $sr^{-1}$ $day^{-1}$)** | **Past 24 Hours (Yes/No)** | **Day 1 (00-24 UTC)** | **Day 2 (00-24 UTC)** | **Day 3 (00-24 UTC)** | **Day 4 (00-24 UTC)** |
|---|---|---|---|---|---|---|
| **Probability (Exceedance)** | | | **(%)** | **(%)** | **(%)** | **(%)** |
| **Active** | **≥ 2 MeV ≥ $1x10^{8}$** | No | 99 | 50 | 10 | 30 |
| **Very Active** | **≥ 2 MeV ≥ $1x10^{9}$** | No | 1 | 1 | 1 | 1 |

**Figure 6: Past 84 hours at L1 magnetometers as recorded at ACE and DSCOVR (here used as a proxy for CH67's fast wind given unstable speed measurements), as well as GOES16 high energy electron flux. Current levels are likely to be near equilibrium, but are expected to be attenuated within 36 hours by the 09 November CME's arrival.**

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